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Note on the Effect of Boundary-layer Suction on Separation

By

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It is well known that the separation point of a boundary-layer flowing over an impermeable surface is defined by the vanishing of the skin friction at that point. Previous investigations have assumed that this condition applies equally to the flow over a porous surface through which the boundary layer is being withdrawn by suction. This appears, however, not to be strictly accurate, and the object of this note is to examine the significance of the distinction and to suggest by means of physical arguments the general character of the flow near a separation point.

Consider the possible origins and destinations of the fluid in the neighbourhood of a separation point. It can come either from upstream or from the wake and it can go either into the surface or downstream to the wake. Thus there are four distinct regions of fluid motion, and they must be arranged as shown in Fig. 1, with a stagnation point S in the middle. The point S should be regarded as the true separation point and is given by the conditions $u = 0, v = 0$. The curve defined by $u = 0$ passes through S and meets the surface at the point P where the skin friction vanishes. At a distance downstream the curve $u = 0$ must lie in the region C, and it seems most probable that it lies entirely within the regions C and A, and that P therefore is in the region A. Hence it may be expected that the actual separation takes place further downstream than the point indicated by consideration of the skin friction. The difference will not usually be large, but one instance in which this effect may be important is that of the flow near a well-rounded trailing edge. Here the flow, which we suppose symmetrical, might be as in Fig. 2, with a region of negative skin friction in the immediate neighbourhood of the trailing edge. Since the velocity at the edge of the boundary layer is low this region may be expected to be of greater magnitude than is usual, and so the suction velocity might be reduced to a value much lower than that required to ensure positive skin friction (when P coincides with O). The branch of the curve $u = 0$ which proceeds from P does not pass through S in this figure, but probably returns to the surface at O, the actual trailing edge.*

The boundary layer becomes very thick near O, the rear stagnation point. This indicates that a large suction velocity will be needed to suppress the wake and give complete pressure recovery at O, although a considerably smaller amount of suction may prevent separation. The boundary-layer equations will fail in this region, so that it will be difficult to predict theoretically the suction quantities required in the two cases.

The main disadvantage of the separation condition proposed here is the difficulty of applying it to boundary-layer calculations, since it is much simpler to find how the skin friction behaves as a function of x than it is to examine the distribution of u and v through the boundary-layer. It is known that for flow without suction the presence of a singularity makes it difficult to find the exact position of the separation point, and if with suction the corresponding singularity is at P it will probably not be possible to continue the solution as far as S. It would be very useful to have an accurate solution of the boundary-layer equations with suction near a separation point, in order to elucidate further the conditions near the separation and to discover whether there is in fact a singularity at P.

* This can be seen from the following considerations. On OS $u = 0$ and v increases from a negative value at the surface to a positive value at infinity, passing through 0 at S. Now if the branch of the curve $u = 0$ which proceeds from P cuts OS, it must do so at a point where $\partial u/\partial x = 0$. But $\partial v/\partial y = 0$ also at such a point, from continuity, so that v is stationary there. This is, in general, the case only at O, and so the branch of $u = 0$ proceeding from P returns to the surface at O.

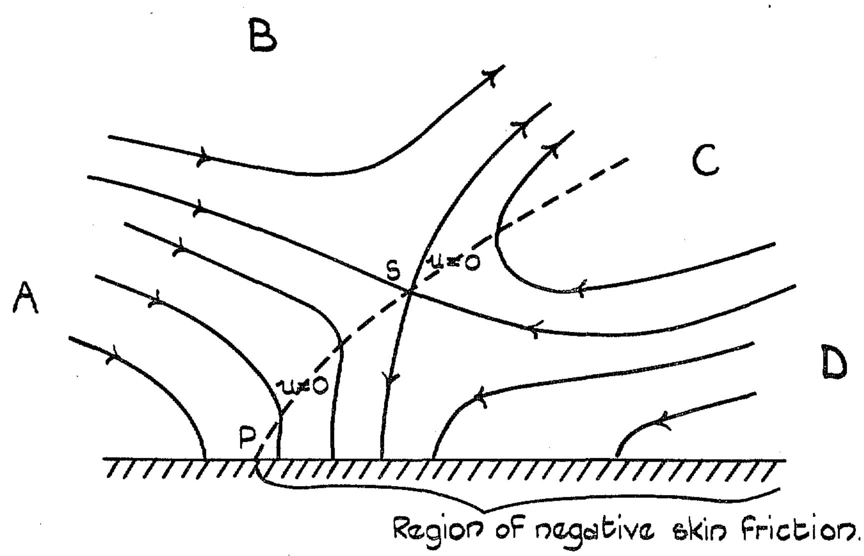

FIG. 1

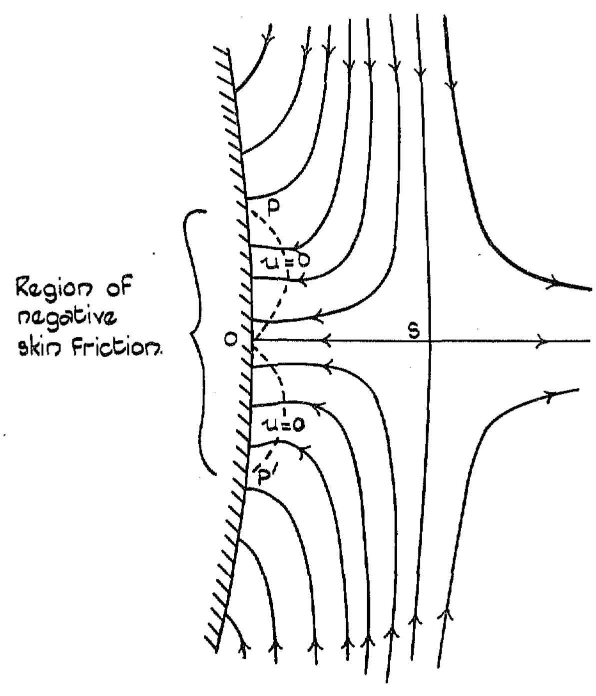

FIG. 2

J4246 Wt.13/806 K.9 4/51 D&Co. 34/263

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